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Recycled Construction and Demolition Wastes as filling material for geosynthetic reinforced structures. Interface properties

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A B S T R A C T

Construction and Demolition Wastes (C&DW) are increasingly being reused in civil engineering applications, mainly in concrete production and base layers of roadway infrastructures. However, frequently the fine grain portion of these recycled aggregates is not considered suitable for those applications being landfilled instead of recycled. Moreover, the value-added utilisation of recycled C&DW in the construction of geosynthetic reinforced structures (steep slopes and retaining walls) is almost an unexplored field. This research assesses the feasibility of using fine-grain recycled C&DW as filling material of geosynthetic reinforced structures (GRS), appraising the physical, mechanical and environmental characterization of the construction and demolition material (C&DM), as well as, the direct shear and pullout behaviour of the interfaces between this material and three distinct geosynthetics (two geogrids and one geocomposite reinforcement or high strength geotextile). Direct shear tests results have shown that fine-grain recycled C&DW, properly compacted, exhibit similar shear strength to natural soils used commonly in the construction of GRS. The potential contamination of groundwater by these recycled C&DW was evaluated through laboratory leaching tests and, excepting the values of sulphate and total dissolved solids (TDS), this recycled C&DW complies with the provisions of European Council Decision 2003/33/EC for inert materials. High values of coefficients of interaction for C&DW/geosynthetic interfaces, a parameter of utmost importance in the design and performance of GRS, were achieved. The results herein presented support the viability of using these recycled C&DW as filling material for GRS construction.

1. Introduction

The population growth and the rapid industrialization have been generating large amount of wastes all over the world, with a large portion of these wastes produced by the construction industry. The volume of Construction and Demolition Wastes (C&DW) is generated in large quantities, mainly in urban areas, causing damage to the environment by the lack of suitable sites for the disposal and also by the society's inattention (Poon, 2007). According to the environment department of the European Commission, C&DW is one of the heaviest and most voluminous waste streams generated in the European Union (EU). It accounts for approximately 25%–30% of all waste generated in the EU and consists of numerous materials, including concrete, bricks, gypsum, wood, glass, metals, plastic, solvents, asbestos and excavated soil, many of which can be recycled (European Commission, 2015).

There is a high potential for recycling and re-use of C&DW, as demonstrated by the numerous studies, with positive results, that have been carried out on the use of recycled aggregates from Construction and Demolition (C&D) materials in base and subbase layers of roadways (Arulrajah et al., 2013a; Barbudo et al., 2012a; Leite et al., 2011; Poon and Chan, 2006; Vegas et al., 2008; Vieira and Pereira, 2015c; Xuan et al., 2015; Rahman et al., 2015) and in concrete production (Behera et al., 2014; Bravo et al., 2015; Medina et al., 2014; Mefteh et al., 2013; Rao et al., 2007; Silva et al., 2014, 2016).

Recycling and reuse C&DW has become a topic of global concern and there is an urgent need to develop research into alternative applications for these recycled C&D materials. The fine grain portion of recycled C&DW is commonly not considered appropriate for use in concrete or roadway base layers due to the high content of fines and scattering of its constituents (soil, glass, concrete,

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mortars, clay masonry units, …). Recent studies have been presented on the use of fine aggregates coming from C&DW as alternative pipe backfilling material (Rahman et al., 2014) and as filling material for geosynthetic reinforced structures (Santos et al., 2013; Vieira and Pereira, 2015a,b).

This paper presents results of the physical, mechanical and environmental characterization of a fine grain recycled C&DW, as well as, the direct shear and pullout behaviour of the interfaces between C&DW and three different geosynthetics.

The interaction mechanism between the geosynthetic and the filling material has an utmost importance in the design of geosynthetic reinforced structures (steep slopes and retaining walls). This mechanism depends on the fill properties, reinforcement characteristics and interaction between both elements (fill and reinforcement). The accurate identification of the interaction mechanism (shear or pullout) and the choice of the most suitable test for its characterization are key factors in GRS design.

Fig. 1 presents a potential failure mechanism of a reinforced steep slope. In upper area of the retained or supported backfill mass, the reinforcement is pulled out, so the soil-reinforcement interaction can be best characterised by pullout tests. Near the base of the slope, sliding in the interface is expected and the interaction between the two materials is better characterised through direct shear tests (Vieira et al., 2013).

Over the last decades many researchers have been investigated the behaviour of soil-geosynthetic interfaces through pullout tests (Esmaili et al., 2014; Ferreira et al., 2015b; Lopes and Ladeira, 1996b; Moraci and Cardile, 2009; Nayeri and Fakharian, 2009; Palmeira, 2004; Pinho Lopes et al., 2015) and direct shear tests (Ferreira et al., 2015a; Lee and Manjunath, 2000; Liu et al., 2009; Vieira et al., 2015; Vieira et al., 2013). Some studies relating to the direct shear behaviour of recycled C&DW/geosynthetic interfaces have also been arising in recent years (Arulrajah et al., 2013b, 2014; Vieira and Pereira, 2015b; Vieira et al., 2014). There are no known studies on the pullout behaviour of geosynthetics embedded in recycled C&DW.

The effect of soil moisture content on soil/geosynthetic interfaces shear strength has been studied by several authors (Abu-Farsakh et al., 2007; Esmaili et al., 2014; Ferreira et al., 2015a,b; Hatami and Esmaili, 2015). In general, these studies have indicated that the interface shear strength can reduce at higher moisture contents, especially in soils containing considerable amount of fines. However, considering that during construction the optimum or slightly lower moisture content is adopted, this study was carried out for recycled C&DW compacted at its optimum moisture content.

This paper deals with the physical, mechanical and environmental characterization of an alternative filling material, as well as, the study of the interfaces between that material and three different geosynthetics through direct shear and pullout tests.

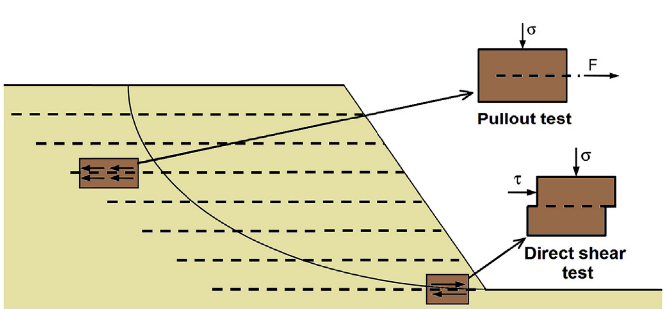

Fig. 1. Potential failure mechanism of a reinforced steep slope and the most suitable laboratory test for interface characterization.

2. Materials and methods

A fine grain recycled C&DW coming from housing demolitions and cleaning of lands with illegal deposits of C&DW was used in this study. The recycled material was collected from a single batch in a Portuguese recycling plant located in the centre of the country. After transportation the recycled C&DW was stored in three big containers. The physical and environmental characterization of the material was carried out with samples resulting from the mixing of portions coming from each container.

The constituents of this recycled C&DW have been evaluated following the European Standard EN 933-11 (2009), with a small change concerning the non-inclusion of soils in the constituent “other materials”. The sample, with weight of 20 kg approximately, was dried at 40 °C, the floating particles were removed and the “clays and soils” were separated. Using a magnifying glass, a pair of tweezers and a magnet, the constituents were sorted out in the 6 classes defined by EN 933-11 (2009): R_c, concrete, concrete products, mortar, concrete masonry units; R_u unbounded aggregate, natural stone, hydraulically bound aggregate; R_b, clay mansonry units, calcium silicate masonry units; R_a, bituminous materials; R_g, glass; X, other materials.

The constituents of the recycled C&DW are listed in Table 1. This recycled material comprises mainly concrete, unbounded aggregates, masonries and soils. It is worth remembering that the C&DW came from housing demolitions and cleaning of lands with illegal deposits.

The particle size distribution determined by sieving and sedimentation of the material is represented in Fig. 2. The gradation of the material was first determined following the European Standard EN 933-1 (2009) for aggregates. However, as this recycled material has significant fines content, the particle size distribution was also determined according to ISO/TS 17892-4 (2004). The specified gradation limits for backfill materials of mechanically stabilized earth walls (MSEW), segmental retaining walls (SRW) and reinforced soil slopes (RSS) specified by the Federal Highway Administration (FHWA, 2010) and the National Concrete Masonry Association (NCMA, 2010) are also represented in Fig. 2.

The particle size distribution of the C&DW is consistent with the requirements of FHWA for reinforced soil slopes (RSS) and the requirements of NCMA for segmental retaining walls (SRW). The gradation limits for backfill materials of MSEW are not fulfilled by this recycled material.

The use of alternative filling materials imposes environmental concerns regarding the potential contamination of groundwater. Thus, the assessment of the release of dangerous substances by the recycled C&DW must be performed. To evaluate the short term release of contaminants of the recycled C&DW, laboratory leaching tests, in accordance with the European Standard EN 12457-4 (2002), were carried out.

Following the standard EN 12457-4 (2002), the material was sieved through a 10 mm sieve. The oversized particles were crushed and added to the laboratory sample. Then an aliquot of the sample was dried at 105 °C and the dry weight was evaluated.

Approximately 90 g of the dried sample was moved to a 1 litre (l) leaching bottle and the leachant (water) was added at a liquid to solid ratio of 10 l/kg (L/S = 10). After that, the leaching bottle was shaken for 24 h in a shaking device. The suspended matter was then filtered through a 0.45 μm membrane filter and aliquots of the filtrated leachate were transferred into separate containers, suitable for the individual analyses.

The Federal Highway Administration (FHWA, 2010) recommends, for the construction of mechanically stabilized earth walls and reinforced soil slopes, using backfill materials with an organic content of less than 1%. The evaluation of the organic content